(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 134 698 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.09.2001 Bulletin 2001/38

(51) Int Cl.⁷: G06T 5/40

(21) Application number: 00200889.4

(22) Date of filing: 13.03.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

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# (54) Video-apparatus with histogram modification means

(57) A video-apparatus comprises histogram modification means to match at least luminance signals (Y) for separate pixels to prescribed values. The histogram modification means comprises a first memory (3) with a first look-up table to correct the video luminance signals (Y), while a second memory (4) with a second look-up table is provided, the values within the second look-up table (4) being derived from the values in the first look-up table (3) and being applied to correct the color-difference signals (U and V). Preferably, in order to obtain a distribution of a rounding-off error over a pixel's neighbor, each of the channels for the luminance (Y) and color-difference signals (U and V) comprises a closed lsb (least significant bit) correction loop (14, 14') with a quantizer (15, 15') and a pixel memory (16, 16'), the input of the lsb correction loop being formed by the corrected luminance and corrected color-difference signals respectively.

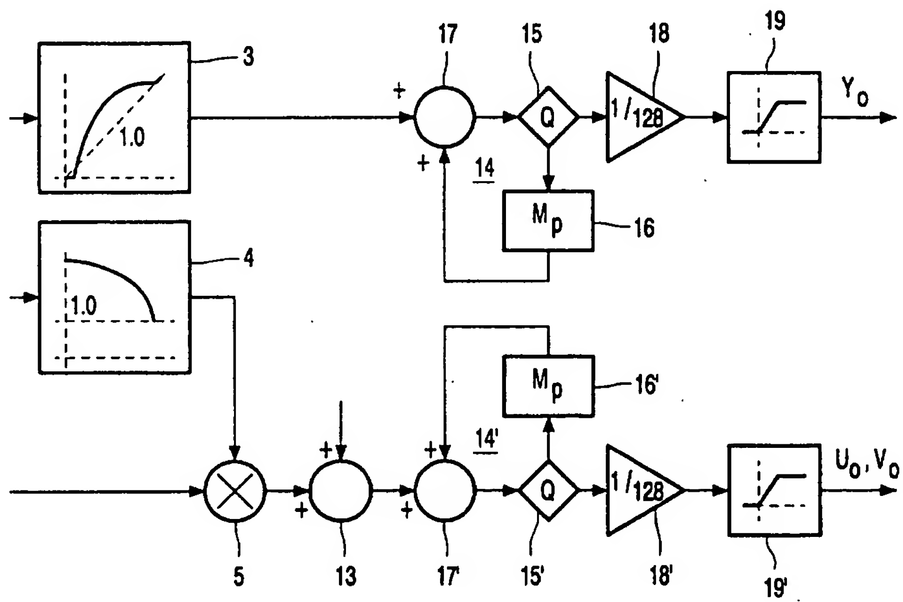


FIG. 2

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## Description

[0001] The present invention relates to a video-apparatus comprising histogram modification means to match at least luminance signals (Y) for separate pixels to prescribed values, the histogram modification means comprising a (first) memory with a (first) look-up table (LUT) to correct said video luminance signals (Y).

[0002] Video-image information may be composed of three components: primary color signals $E'_G$, $E'_B$, $E'_R$ or signals derived therefrom, particularly a luminance signal $E'_Y$ and color-difference signals $E'_{B-Y}$ and $E'_{R-Y}$. The primary color signals $E'_G$, $E'_B$, $E'_R$ are the gamma corrected signals corresponding to green, blue and red information respectively. A gamma correction is a compensation for CRT non-linearity by introducing a compensating non-linearity in the system. The luminance signal $E'_Y$ and the color-difference signals $E'_{B-Y}$ and $E'_{R-Y}$ are derived from the primary color signals and are, applied in PAL systems, indicated by $E'_Y$, $E'_U$ and $E'_V$, or, for the sake of simplicity, by Y, U and V.

[0003] US-A-4,450,482 describes a video-apparatus with histogram modification means. The histogram modification therein is only realized for luminance signals Y. The histogram modification means perform contrast enhancement; it implies a non-linear transfer function to be applied to video signals in order to get a more even distribution of black, grey and white levels. In said known histogram modification first the distribution function of the brightness levels of a representative set of pixels, i.e. a histogram, is measured. As already said, it may show an uneven distribution of dark, medium or bright pixels. A correction function is calculated that, when applied to the video signals, yields a more evenly distributed histogram, but not necessarily a flat histogram. The correction may be called a 0-dimensional correction because each new pixel value is only a non-linear function of the old pixel at the same spatial and temporal position. The non-linear correction function can be quite complicated, so it will usually involve a memory with a look-up table (LUT). By means of the look-up table a luminance signal $Y_i$ of a pixel will be corrected to a value $Y_o$.

[0004] It is, inter alia, an object of the invention to provide an improved histogram modification. To this end, the invention provides a histogram modification as defined in the independent claims. Advantageous embodiments are defined in the dependent claims.

[0005] In practice it appeared to be desirable to apply histogram modification correction in each of the three video-information channels for the luminance and color-difference signals. Therefore, according to one embodiment of the invention, the video-apparatus as described in the opening paragraph is characterized in that a second memory with a second look-up table is provided, the values within said second look-up table being derived from the values in the first look-up table and being applied to correct the color-difference signals (U and V).

[0006] As the sample rate of the luminance signals (Y) is usually twice the sample rate of the color-difference signals (U and V), a sample rate converter is provided to adapt the sample rate of the luminance signals (Y) to that of the color-difference signals (U and V), the output signals of said sample rate converter being supplied to the second memory.

[0007] The first look-up table contains corrected luminance values in accordance with a predetermined correction function; to obtain corrected color-difference signals the second look-up table contains gain-values, derivable from said correction function, e.g. being formed by values of the first derivative of the correction function, while the apparatus further comprises a multiplier, in which the color-difference signals (U and V) are corrected by multiplication with the respective gain-values.

[0008] As in practice color-difference signal zero-values are represented by a certain digital number and such signals with zero-value must not be corrected each of the color-difference signals is decreased by an offset value before multiplication and increased by said offset value after multiplication.

[0009] In a preferred embodiment error-propagation is applied; this means that, in order to obtain a distribution of a rounding-off error over a pixel's neighbor, each of the channels for the luminance (Y) and color-difference signals (U and V) comprises a closed lsb (least significant bit) correction loop with a quantizer and a pixel memory, the input of the lsb correction loop being formed by the corrected luminance and corrected color-difference signals respectively.

[0010] From the above mentioned US-A-4,450,482 histogram modification is known. Apart from this document many histogram algorithms have been developed. Most of them are rather complicated because for each brightness level in the histogram a corrected value is calculated. According to the invention a histogram modification unit is provided by means of which from a measured histogram a correction function is calculated on the basis of only three levels, particularly black, grey and white brightness levels in the measured histogram with only three control operators, particularly offset, gain and gamma, according to the relation:

$$V_o = [(V_i + \text{offset}) \cdot \text{gain}]^{\text{Gamma}}.$$

All corrected values are obtained from this relation.

[0011] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

[0012] In the drawings:

Fig. 1 shows a basis block diagram of a correction unit for luminance and color-difference signals;

Fig. 2 shows part of this correction unit extended with error-propagation means;

Fig. 3 illustrates the control operators for histogram

modification according the invention; and
Figs. 4-6 are diagrams to explain the algorithm for histogram modification.

**[0013]** Fig. 1 shows a luminance signal channel 1 and a color-difference channel 2. As both color-difference channels for U- and V-signals are equal, only one of these channels is indicated. Nevertheless one channel may be sufficient, if the U- and V-signals are transported on multiplex basis.

**[0014]** In order to correct the input luminance signal $Y_i$ a memory 3 with a look-up table (LUT) is provided, which look-up table contains luminance output signals $Y_o$, which are in relation with the luminance input signals $Y_i$ according to a prescribed non-linear correction function: $Y_o = f(Y_i)$. So, the content of the LUT 3 is based on a histogram of the input luminance signal $Y_i$. As the color-difference signals $U_i$ and $V_i$ must be corrected with a corresponding value of the variable gain factor $Y_o/Y_i$, a second memory 4 is provided with a look-up table (LUT) containing values corresponding substantially with the gain of the above function. By means of a multiplier 5 the input signals $U_i$ and $V_i$ are multiplied by the respective values from the look-up table in the second memory 4.

**[0015]** As the sample rate of the luminance input signals $Y_i$ is twice the sample rate of the color-difference signals $U_i$ and $V_i$ a sample rate converter 6 is provided, comprising a pixel memory ($M_P$) 7, a down-sample unit 8 for the signals $Y_i$, a down-sample unit 9 for the one-pixel-delayed signals $Y_i(T)$, an adder unit 10 and a factor 2-divider 11. By the divider 11 a signal is delivered to the memory 4 which corresponds with a video signal valid for two successive pixels, whereby the separate pixel values are averaged. Based on this signal the memory 4 supplies a correction signal corresponding substantially with a respective value of $Y_o/Y_i$, stored in the look-up table of memory 4.

**[0016]** In the following it will be assumed that each of the U and V signals is represented by a 8-bits number, the maximum value being 255, corresponding with a color-difference "+1". A monochrome U or V signal, i.e. color difference "0" is then defined by 128. Monochrome U and V signals are not corrected. Therefore a subtractor element 12 is introduced to diminish the U and V signals with an offset color difference value 128 and thus to bring a monochrome signal to a color difference value "0", while after correction in the multiplier 5 by means of an adder element 13 the U and V signals are increased by an offset color difference value 128 so that a monochrome signal can be given again the color-difference value "0".

**[0017]** In the present example the output of the memory 4 is represented by a 8-bits unsigned gain, i.e. the correction factor $Y_o/Y_i$, and the output of the multiplier 13 by a 16-bits U or V value, with 7 bits "behind the comma". These bits must be "discarded" before fully outputting the video signals $U_o$ and $V_o$. This is realized by error propagation; this means a distribution of a rounding-off error each time over a pixel's neighbor. As the output signal of memory 3 is a 15-bits luminance signal value and an 8-bits luminance output signal $Y_o$ must be obtained, this value also has 7 bits "behind the comma", which must be "discarded".

**[0018]** Therefore, in the embodiment of Fig. 2, each of the channels for the luminance (Y) and color-difference signals (U and V) comprises a closed lsb (least significant bit) correction loop 14, 14' respectively, with a quantizer 15, 15' and a pixel memory 16, 16', the input of the lsb correction loop 14, 14' being formed by the corrected luminance and corrected color-difference signals respectively. By adding every time the 7 lsb's, representing a quantization error, of a foregoing pixel value to the Y, U and V value respectively in an adder element 17, 17', a recycling of the 7 lsb's in a pixel delay is obtained, which guarantees that the average video level will be correct down to the last lsb's, in spite of the quantization back to 8 bits by means of the 128-divider 18, 18'. Because the non-linear transfer functions in the look-up tables require a longer word length to be able to make a sufficient precize quantization in the Y-channel and a sufficient variation in the differential gain in the U and V channels, the information in the added lsb's is not just discarded but distributed over the horizontal neighbors to maintain the average accuracy. Such a distribution means "noise shaping". Mainly due to this noise shaping, the luminance and color difference signals may overflow the value +255. To prevent such adverse effects, the 8- and 9-bits output signal of the dividers 18, 18' are led to clippers 19, 19'.

**[0019]** As already indicated the content of memories 3 and 4 may be refreshed each frame period. This is called histogram modification. Histogram modification performs contrast enhancement; it means that the various brightness levels between black and white are distributed better over the entire brightness level scale. As it is well known to determine a histogram, the algorithm will not be further described. In figs. 4A, 5A and 6A a number of simplified histograms is shown for 8 brightness levels. Fig. 4A shows a flat histogram with equally distributed brightness. Fig. 5A shows a histogram of a dark scene with more dark pixels. Fig. 6A shows a histogram of a bright scene with a set-up, i.e. a positive offset, for black and with more bright pixels. Figs. 4B, 5B and 6B show the corresponding cumulative histograms, calculated from the histograms of figs. 4A, 5A and 6A. Using linear interpolation the levels for 'black', 'grey' and 'white' are estimated where the cumulative histograms crosses the 3%, 37% and 97%. Before the grey level is estimated, first any large black or white areas are excluded from the histogram; grey is then estimated from the reduced cumulative histogram. This avoids problems due to large black or white side panels which would otherwise distort the picture statistics. After estimation of the black, grey and white levels temporal non-linear low-pass filtering is applied to smooth the var-

iations in the histogram modification as blinking pictures are not desired. The non-linear character of the filter process results in a faster reaction to picture black level that goes down (more black) or a white level that goes up (more white) and a slower reaction to less extreme values (a more grey black value and a more grey white value) and as a consequence thereof in a more natural reaction on scene changes. Next the filtered black, grey and white levels are turned into a new look-up table. In this algorithm from the filtered black, grey and white levels three control parameters are calculated, viz. offset, gain and gamma, which determine the Y-transfer function in memory 3. Figs. 4C, 5C and 6C show the transfer functions $Y_o = f(Y_i)$ for the respective histograms.

**[0020]** The control parameters offset, gain and gamma are illustrated in Figs. 3A, 3B and 3C. In all these figures, the output brightness is given in dependency of the input brightness levels. In Fig. 3A the line 20 shows an offset '0'. The lines 21 and 22 show offset lines '>0' and '<0' respectively. These figures show the variation of the brightness for black. The offset parameter is used to 'put black on black'. In Fig. 3B the line 23 shows a gain '1', while the lines 24 and 25 show lines with gain '>1' and '<1' respectively. These figures show the variation of the contrast for white. The gain parameter is used to 'put white on white'. In Fig. 3C the line 26 shows a Γ (Gamma) '1', while the curves 27 and 28 show a Γ '<1' and '>1' respectively. The Γ-parameter us used to move the grey independently from black and white. If a scene contains mostly dark areas then it is advantageous to increase the differential gain near black. This can be done by decreasing the Γ of the video path. If a scene contains mostly bright areas then it is advantageous to increase the differential gain near white. This can be done by increasing the Γ of the video path.

**[0021]** The three parameters can be combined to the following transfer function:

$$V_o = [(V_i + \text{offset})^{*}\text{gain}]^{\text{Gamma}}.$$

This function assumes signals in a range of 0.0, ..., +1.0. By means of only three input values, viz. the filtered black, grey and white levels three control parameters are calculated, viz. offset, gamma and gain, which determine the Y-transfer function in accordance with the above mathematical relation. This relation is a good approximation, however, in the neighborhood of the point $(V_i, V_o) = (0, 0)$ is it necessary to choose a straight line with a limited slope. As substantially the same absolute gain as in the Y-channel is used in the U,V-channels, the content of the look-up table in the memory 3 determines the content of the second look-up table in the memory 4.

**[0022]** It will be clear that the invention is not restricted to the preferred embodiment shown in the drawing. Many alternatives for performing the functions of the various algorithms may be possible. Particularly the above mathematical relation can be replaced by other relations: with the application of three filtered black, grey and white brightness level values three control parameters are required; the choice of these parameters is quite arbitrary. However, the restriction to three brightness level values and the specific choice of the control parameters offset, gamma and gain lead in practice to a sufficient accurate embodiment. These parameters are safe to manipulate with, they will not likely lead to unexpected artifacts like highly visible aliasing or contouring and such like effects.

**[0023]** The embodiments described above are realized by an algorithm, at least part of which may be in the form of a computer program capable of running on signal processing means in a video-apparatus. In so far part of the figures show units to perform certain programmable functions, these units must be considered as subparts of the computer program. Particularly the look-up tables can be realized by part of the computer's memory.

**[0024]** It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

## Claims

1. Video-apparatus comprising histogram modification means to match at least luminance signals (Y) for separate pixels to prescribed values, the histogram modification means comprising a first memory (3) with a first look-up table to correct said video luminance signals (Y), **characterized in that** a second memory (4) with a second look-up table is provided, the values within said second look-up table (4) being derived from the values in the first look-up table (3) and being applied to correct the color-difference signals (U, V).

2. Video-apparatus according to claim 1, **characterized in that** a sample rate converter (6) is provided to adapt the sample rate of the luminance signals

(Y) to that of the color-difference signals (U and V), the output signals of said sample rate converter (6) being supplied to the second memory (4).

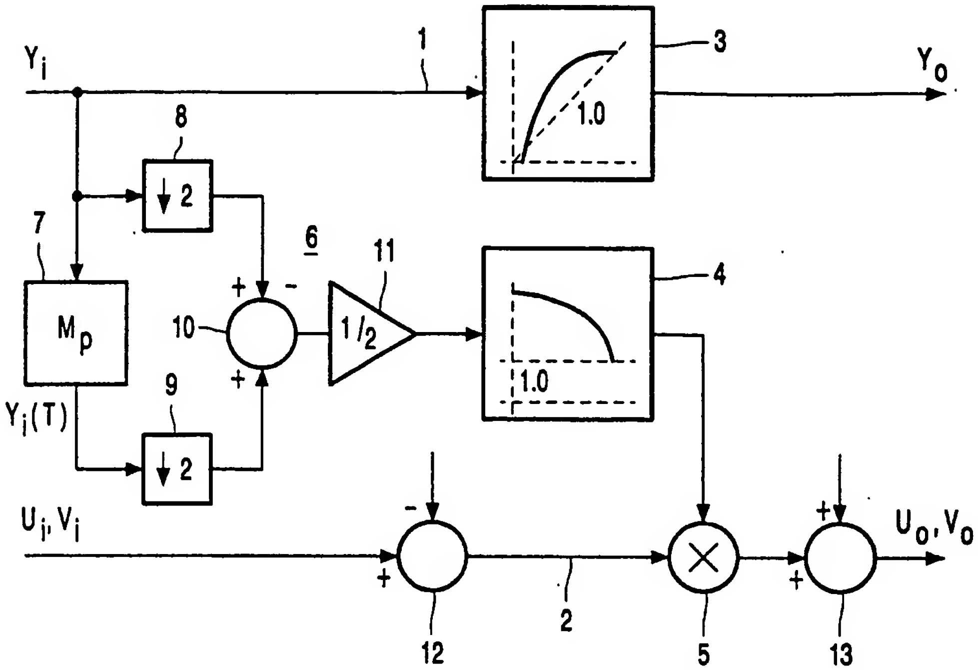
3. Video-apparatus according to claim 1, **characterized in that** the first look-up table (3) contains corrected luminance values in accordance with a predetermined correction function and the second look-up table (4) contains gain-values, derivable from the correction function, while the apparatus further comprises a multiplier (5), in which the color-difference signals (U and V) are corrected by multiplication with the respective gain-values.

4. Video-apparatus according to claim 3, **characterized in that** each of the color-difference signals (U, V) is decreased (12) by an offset value before multiplication (5) and increased (13) by said offset value after multiplication (5).

5. Video-apparatus according to claim 1, **characterized in that**, in order to obtain a distribution of a rounding-off error over a pixel's neighbor, each of the channels for the luminance (Y) and color-difference signals (U and V) comprises a closed lsb (least significant bit) correction loop (14, 14') with a quantizer (15, 15') and a pixel memory (16, 16'), the input of the lsb correction loop being formed by the corrected luminance and corrected color-difference signals respectively.

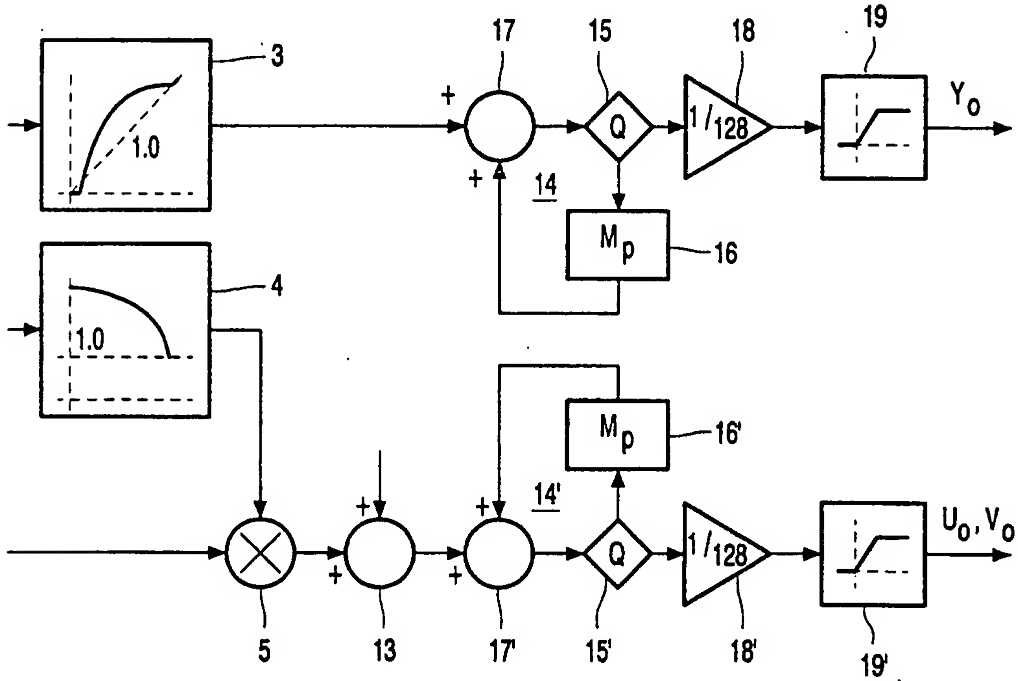
6. Video-apparatus according to claim 1, **characterized in that** a histogram modification unit is provided by means of which from a measured histogram a correction function is calculated on the basis of three, particularly black, grey and white brightness levels in the measured histogram with only three control operators, particularly offset, gain and gamma, according to the relation:

$$V_o = [(V_i + \text{offset})^{*}\text{gain}]^{\text{Gamma}}.$$



Y
i
1
3
Y
o
1.0
8
2
7
6
11
4
M
p
10
1/2
1.0
9
Y
i
(T)
2
U
i
, V
i
U
o
, V
o
12
2
5
13


FIG. 1



17
15
18
19
3
Y
o
Q
1/128
1.0
14
M
p
16
4
1.0
M
p
16'
14'
U
o
, V
o
Q
1/128
5
13
17'
15'
18'
19'


FIG. 2

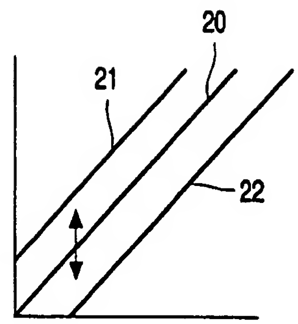



FIG. 3A

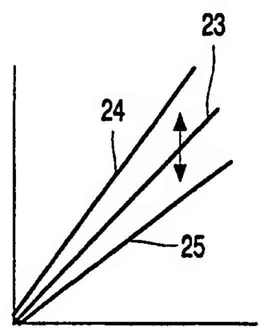



FIG. 3B

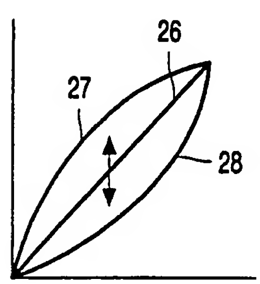



FIG. 3C

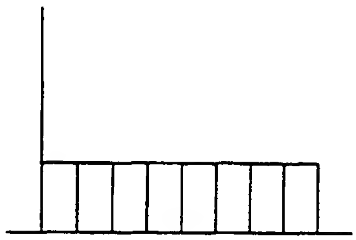


FIG. 4A

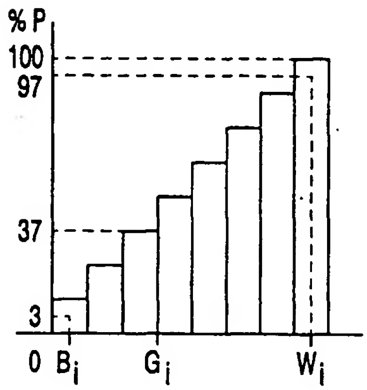



FIG. 4B

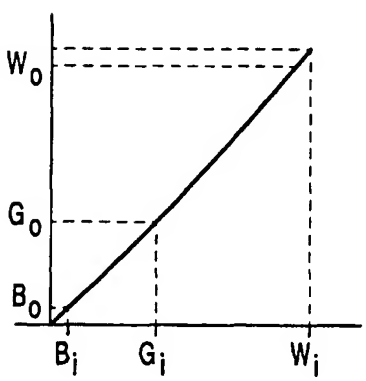



FIG. 4C

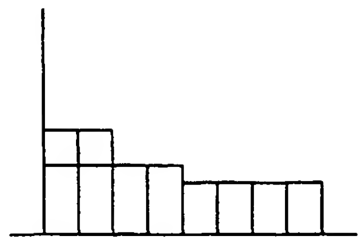


FIG. 5A

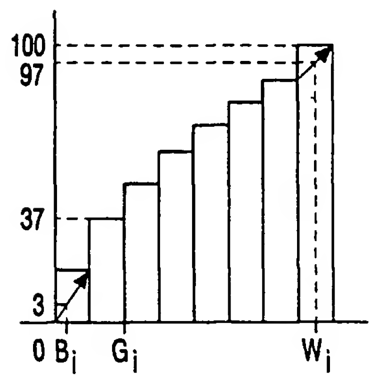



FIG. 5B

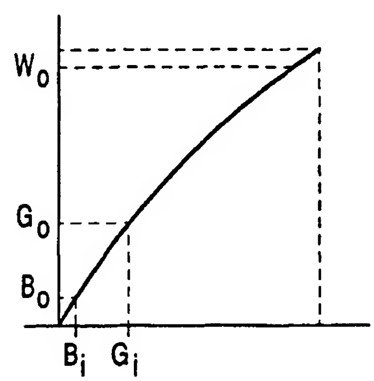



FIG. 5C

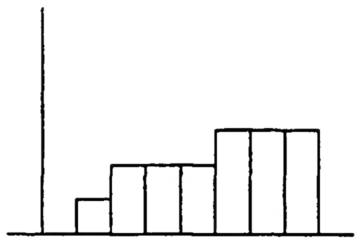


FIG. 6A

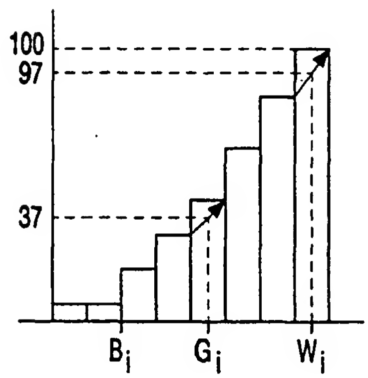



FIG. 6B

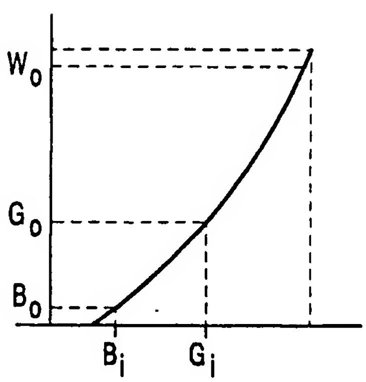



FIG. 6C

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 00 20 0889

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| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 1 September 2000 | Gonzalez Ordonez, O |

CATEGORY OF CITED DOCUMENTS

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